

Laboratory investigation of rejuvenator seal materials on performances of asphalt mixtures

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HIGHLIGHTS

- ▶ We found the rejuvenator seal materials (RSMs) can soften the aged asphalt binder.
- ▶ We found the RSM decrease the rutting resistance of asphalt mixture.
- ▶ We found the RSM effectively decrease the raveling of asphalt mixture.
- ▶ We found the RSM decrease the skidding resistance of asphalt mixture.

ARTICLE INFO

Article history:

Received 9 May 2012

Received in revised form 3 July 2012

Accepted 20 July 2012

Available online 24 August 2012

Keywords:

Rejuvenator seal materials

Maintenance

HMA

Performances

ABSTRACT

The objective of this paper is to investigate the effects of rejuvenator seal materials (RSM) on performances of hot asphalt mixtures (HMA). Firstly, frequency sweep test is conducted to determine the rejuvenating effect of RSM on aged asphalt binders. Then, high temperature performances of RSM treated HMA are studied by means of wheel tracking test, static creep test and indirect tensile test. Lastly, raveling test and skidding resistance test of RSM treated HMA are also performed in this paper. The results indicate that RSM can effectively soften the aged asphalt binder, and the application of RSM may decrease the high-temperature performance of HMA. Moreover, RSM increase the raveling resistance and decrease the skidding resistance of HMA. The results of this paper help to have a better understanding on the effects of RSM on HMA.

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1. Introduction

In order to restore the properties of aged asphalt, many kinds of rejuvenator agents by directly mixing with aged asphalt are widely and successfully used all around the world [1–4]. Unlike the conventional rejuvenator materials, rejuvenator seal materials (RSM) are usually sprayed onto the surface of asphalt pavement. The primary purpose of using rejuvenating seal is to soften the stiffness of the oxidized asphalt pavement surface and thus to extend the life of the pavement [5,6].

RSM has been used in the maintenance of asphalt pavement since 1970s in United States. Recently, with the development of asphalt pavement in China, many preventive maintenance methods, such as micro-surfacing, slurry seal, fog/rejuvenator seal and chip seal are adopted for the purpose to guarantee a good condition during the service process of the pavement. Among these

preventive maintenance methods, fog/rejuvenators seal is a more convince and cheap method to protect the pavement and extend pavement service life, which is attracted an increasing attention in recent years.

Some research studies about the rejuvenating effects of RSM on HMA have been reported. Brownridge found that rejuvenators can penetrate into the voids of pavement, filling them and minimizing the binder oxidation. In addition, the research also validate that RSM could increase the durability and viscosity of the asphalt in the top portion of the pavement by improving the chemical composition of the asphalt binder [7]. Chui-Te Chiu conducted a research on the influence of RSM on asphalt pavement. In this study, three kinds of RSM were applied on a highly aged parking lot pavement. The viscosities of the recovered asphalt binders from different layers of the pavement before and after the treatment were analyzed. They found that RSM showed a considerable softening effect on the old asphalt binders in the top 1 cm of the treated pavement [8]. In addition, RSM also have been applying on airfield asphalt pavement for preventive maintenance. However, only the primary results on skidding resistance was given, and the final recommendations for using asphalt surface

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treatments on army airfields will be made after products have been in service for 5 years [9].

As mentioned above, the researchers mainly focused on the rejuvenating efficiency of RSM, the viscosity and the ductility of the asphalt extracted from HMA treated by RSM were usually measured. Moreover, some performance related problems are happened when the asphalt pavement were treated by RSM. Previous research found that the application of RSM decrease the modulus of asphalt mixture and thus increase the rutting potential of asphalt pavement [4,5,10,11]. In addition, skidding resistance of asphalt mixture also be decreased by RSM [6,12]. However, the rutting and raveling resistance of asphalt mixture treated by RSM has not been comprehensively investigated by multiple performance tests. In addition, the simple and useful methods to study the skidding resistance of asphalt mixture treated by RSM have not been given. These problems provide the motivation to undertake this research.

The objective of this paper is to investigate the effects of RSM on performances of HMA in the laboratory. Some laboratory characterizations of the asphalt binder and HMA are conducted to quantify the changes caused by the treatments of RSM on the surface. Firstly, the rejuvenating effect of rejuvenator seal materials on aged asphalt is determined. Then the high temperature performance, raveling resistance and skidding resistance of treated HMA were studied. From this study, the effects of RSM on performance of HMA can be known better.

2. Materials and experiments

2.1. Materials

The study contains three types of products that were representative of currently marketed asphalt surface treatment products, named C, L and J respectively. Normally, these materials were mainly composed of petroleum solvent, and rejuvenator.

A neat PG 70–22 binder was selected in this study. The basic properties of asphalt binder is as follows: penetration 75 (0.1 mm); soft point, 44.5 °C; ductility, 167.5 cm.

HMA used in this paper was designed by Marshall methods. The basalt aggregates gradation is shown in Fig. 1. Besides, the optimum asphalt content was 5.0% by weight of aggregates.

2.2. Experiments

2.2.1. Frequency sweep

To determine the rejuvenating effects of RSM, the asphalt used in this research was aged by RTFOT. RTFOT was carried out according to AASHTO T240, which was widely used all over the world to simulate the short term aging of asphalt binder.

After the asphalt was aged, RSM were mixed with aged asphalt at the percentage of 5 wt%. This percentage is chosen based on the conventional test of blend asphalt in our previous study, such as penetration, soft point, and ductility tests. Then, DSR (dynamic shear rheometer) was used to measure the complex modulus and phase angle of the mixed asphalt with different frequencies at different temperatures.

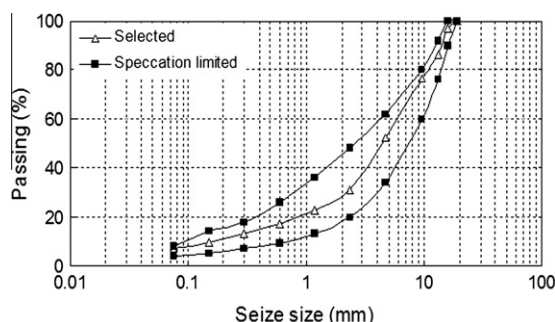


Fig. 1. Grading curves of aggregates.

2.2.2. Static creep test

The static creep test was carried out using Universal Testing Machine (UTM) to apply constant axial compressive stress to asphalt specimens. The specimens of 100 mm diameter and 64 ± 1 mm height were prepared and then tested at 60 °C. The HMA specimens were coated with the dosage of 300 g/m². A compressive stress of 100 KPa was applied on the specimens for 3600 s, then the load was removed and the deformation recovery was monitored for 4500 s. Accumulated microstrain was calculated as the ratio of the measured deformation to the initial specimen height according to the following equation:

$$\varepsilon = h/H_0 \quad (1)$$

where ε is the accumulated microstrain occurred in the specimen during a certain loading time at a certain temperature, h is the axial deformation, mm; H_0 is the initial specimen height, mm.

2.2.3. Wheel tracking test

The wheel tracking test was employed to measure rutting resistance of HMA. The experiment conditions were as follows: slab samples with 300 mm length, 300 mm width and 50 mm thickness were placed in dry atmosphere at 60 ± 0.5 °C for 4 h, and then a wheel pressure of 0.7 MPa at a speed of 42 ± 1 cycles/min was loaded at the surface of slab for a loading period of 60 min. In addition, RSM were brushed onto the surface of HMA specimens with the dosage of 400 g/m² prior to wheel tracking test.

2.2.4. Indirect tensile strength test

Indirect tensile strength test was a popular approach to get the strength of HMA. In this study, the cylindrical HMA specimens with the height of 63.5 ± 2 mm and diameter of 100 mm surface treated with three types of RSM at the dosage of 300 g/m². After RSM were fully cured, the indirect tensile strength of treated specimens can be tested by applying a displacement loading rate of 50 mm/min at the temperature of 25 °C with UTM. At the meantime, the strengths of HMA specimens without treated by RSM were also measured as comparison.

2.2.5. Raveling test

In order to study the effects of RSM on raveling resistance of HMA, Cantabro raveling test was conducted. Firstly, the HMA specimens were prepared by Marshall compaction, and then the specimens were coated with these three types of RSM with the dosage of 300 g/m². The treated HMA specimens were placed in the water bath for 96 h at the temperature of 60 °C, and then were placed in the laboratory at room temperature for 24 h. After this, the Cantabro raveling tests were conducted according to ASTM method C131. The weight loss percentage of tested specimen was used as an indicator of the ability to resist raveling.

2.2.6. Skidding test

British Pendulum Tester (BPT) was used to evaluate the skidding resistance of the road surfaces based on ASTM E303. The values measured were referred to as British pendulum numbers (BPN) for flat surfaces. Firstly, the BPT was conducted on the surface of HMA samples, and then three types of RSM (C, J and L) were sprayed on the surface of the same sample separately and individually. BPT was performed after the RSM were full cured.

Sand patch test was conducted to determine the average macro-texture of asphalt mixture according to ASTM E965–96. RSM (C, J and L) were sprayed on the surface of one group of HMA. Then a certain volume of ground sand was poured on the surface of HMA with and without RSM. The sand was spread by making a circular area with a disk by holding the disk horizontally to make sure the surface was filled to the level of the highest points. The texture depth (TD) was calculated with the following equation:

$$TD = \frac{4000V}{\pi D^2} \quad (2)$$

where V is the volume of sand sprayed on the surface asphalt mixture, and D is the average diameter of sand patch on asphalt mixture.

3. Results and discussion

3.1. Master curve

Fig. 2 shows the master curve of aged asphalt with the RSM and control aged asphalt binder without RSM. The reference temperature is determined as 50 °C because the rejuvenating effect is more easily to be observed in medium or high temperature. The time-temperature superposition principle, which is widely used for polymer materials, is employed to analyze rheological data for asphalt in this study [13]. As seen in this figure, the aged asphalt binders with RSM exhibit lower complex than that of control aged

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